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Chapter 8

Husbandry of azooxanthellate soft corals (Anthozoa: Octocorallia) in captivity: preliminary results

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ABSTRACT

Soft corals containing symbiotic algae are popular additions to coral reef aquariums due in part to their minimal husbandry requirements. However, azooxanthellate octocorals are also common in the ornamental trade and their demand by hobbyists is a result of the typically vibrant colors displayed by these soft corals. Unfortunately, azooxanthellate octocorals have a poor track record of success in closed systems. In 2005, a program was developed at AquaTouch to investigate the husbandry requirements of some azooxanthellate octocorals in closed systems. This paper presents the initial results of experiments carried out for one year, focusing on gorgonians. It describes the aquarium system designs, water flow, and feeding requirements for these corals. This program was expanded in 2006 to include an azooxanthellate octocoral belonging to the family Paralcyoniidae. Information on the captive care requirements for the genus *Studeriotes*, Thomson & Simpson, 1909 is given. Environmental design and husbandry techniques developed during this study can be used to add new corals to the growing list of octocorals now on display in public aquariums.

INTRODUCTION

Octocorals make up a significant part of coral reef communities with estimates exceeding two thousand eight hundred species (Bayer, 1981, www1) from forty-five known families. Among soft corals, brightly colored specimens are of interest to divers, snorkelers, and the ornamental aquarium trade. The azooxanthellate or non-photosynthetic genera and species exhibit a range of colors containing white, colored, or translucent polyps. They often have a soft, fleshy appearance as in the case of the genera *Chironephthya, Dendronephthya, Nephthyigorgia* and *Scleronephthya*. Others like sea fans or gorgonians exhibit a range of branch configurations. Azooxanthellate gorgonian colonies are usually red, orange or yellow in color and can be quite prominent in some reef communities (Grasshoff, 2000; Grasshoff and Bargibant, 2001). Bright colony colors and absence of brownish pigment in the polyps is usually indicative of corals lacking symbiotic golden-brown algae called zooxanthellae in their gastrodermal tissue layer. Without an algal component, these corals must rely on meeting their nutritional needs from food particles taken up from the water column known as heterotrophic feeding. Nutrition is acquired through the capture of prey, absorption of organic molecules through the layers of tissue, filtered from water exchanged in the gastric cavity, or collected in net-like mucus secretions. Polytrophic feeding occurs in many octocorals through a combination of these methods. Lewis (1982) and Delbeek and Sprung (1997) give a thorough treatment of octocoral feeding strategies. In addition to food uptake, water current velocity and polyp densities influence the physiological needs of azooxanthellate octocorals.

Octocorals are quite popular in the aquarium trade and many genera have been regularly available for over fifteen years (Wilkins and Birkholz, 1992). Historically, azooxanthellate octocorals have been very challenging to maintain in closed system aquaria. Most species typically exhibit a slow decline in health with very few records of growth or reproduction. Much of the modern aquarium literature has

suggested that these corals should not be collected or purchased until more research can be done (Delbeek and Sprung, 1997; Fosså and Nilsen, 1998; Brockmann, 2001). Once there is a better understanding of the specific needs of these corals in closed systems, it may be possible to develop more advanced systems to display azooxanthellate octocorals in public aquaria. With their poor record of long-term survival in captivity, a study was designed in 2004 to examine some azooxanthellate octocorals and identify the primary criteria necessary for successful captive husbandry. Since no documented husbandry studies for this group of octocorals could be found, this project is a pioneering foundation for more detailed experiments in the future.

Azooxanthellate octocorals survive in their natural habitat due in large part to the water motion they receive. It is a critical component, providing both nutrients and planktonic foods. The genus *Dendronephthya* has been documented in areas of consistent water current (Borneman, 2001) and the azooxanthellate gorgonian family Melithaeidae is found throughout the Indo-Pacific region on current-swept walls and overhangs (Fabricius and Alderslade, 2001).

Water flow is an important factor in the design of closed systems for azooxanthellate octocorals, from the perspective of both velocity and form. The currents created in an aquarium for azooxanthellate octocorals are necessary to encourage polyp expansion and allow for prey capture. The husbandry experiments designed for this study also examined the densities of food available in the water stream. Water motion is well documented as an attribute of coral reef development (Sebens, 1992; Sebens and Johnson, 1991). Most published studies of water flow velocities and feeding responses in octocorals have examined which polyps are capturing food particles at different velocities and the degree of polyp expansion (Dai and Lin, 1993; Fabricius *et al*., 1995b; Kim and Lasker, 1997; Patterson, 1991). In these studies the octocoral colonies were observed to have the ability to capture prey in a wide range of velocities yet many showed a near optimal velocity range of 8 to 12 $cm.s^{-1}$.

The first group selected for investigation in this study was the azooxanthellate gorgonians. Their choice was based primarily on the successful husbandry of zooxanthellate specimens in captivity, observations of sea fans and gorgonians in the wild, and the increased diversity of live and preserved zooplankton foods currently available in the aquarium industry. Specific family and genus choices were made based on a few criteria. First, specimens must be obtainable in an apparently healthy condition from collection sites in a reasonable time, giving them the best chances to adapt to captive conditions. The second factor in choosing specimens was based on the average polyp size. Colonies with polyps greater than or equal to 0.5 millimeters in diameter were chosen with the assumption that larger polyps would be able to consume the range of zooplankton foods currently available from commercial sources. Lastly, polyp densities on a branch or within a colony were considered. Highly dense aggregations of polyps were avoided and species with wider placement of polyps were selected. It was postulated for these experiments that colonies with either fewer polyps or increased spacing between polyps would have better potential for prey capture, consumption, and diffusion of any micro-boundary layers of water.

In 2006, after completion of the gorgonian experiments a second azooxanthellate octocoral belonging to the genus *Studeriotes* was selected for investigation of its captive husbandry requirements. Species of *Studeriotes* occur in soft bottom sediments and are often found in protected areas, sheltered from wave action where they are subjected to tidal water flow (K. Venkataraman, pers. com.). Four nominal species of *Studeriotes* were located in the literature, the type specimen *Studeriotes mirabilis* (Thomson and Simpson, 1909), *S. debilis* (Thomson and Dean, 1931), *S. semperi* (Studer, 1888) and *S. spinosa* (Thomson and Dean, 1931). Species of this genus are lobate with widely spaced polyps measuring up to two millimeters in diameter aligned in roughly shaped rows along the lobes. Colonies have two distinctly different sections. The lower, basal portions of colonies are very rigid, comprised of large sclerites or skeletal elements. This basal region remains buried in soft sediments. The large, fleshy lobes in the upper portion of the colony swell with water rising into the water column. A positive internal water pressure supports the lobes. The lobes are capable of expelling the internal water, completely retracting into the cup-shaped support of the basal portion of the colony (Figure 1).

Nine specimens of *Studeriotes* were kept in a lagoon-like closed system habitat for a

period of eleven months. Substrate materials were compared to see if the basal portion of colonies could adapt to grain sizes that were larger than those typically found in their natural habitat. The ability for colonies of this genus to bury their basal cup, orient the lobes in an upright manner, and go through the process of cyclical expansion were considered to be important behaviors in identifying a proper substrate for an aquarium display. Colonies were also examined for food particle ingestion and their growth was monitored.

MATERIALS

Experimental organisms

The octocorals used in these experiments originated from the Pacific Ocean and Caribbean Sea. Specimens from the Pacific were obtained through the marine ornamental trade chain of custody, and originated in Indonesia. Multiple specimens of each species were acquired. They were identified to the genus level following the taxonomic methods given by Janes and Wah (2007). Nine specimens of *Studeriotes* were

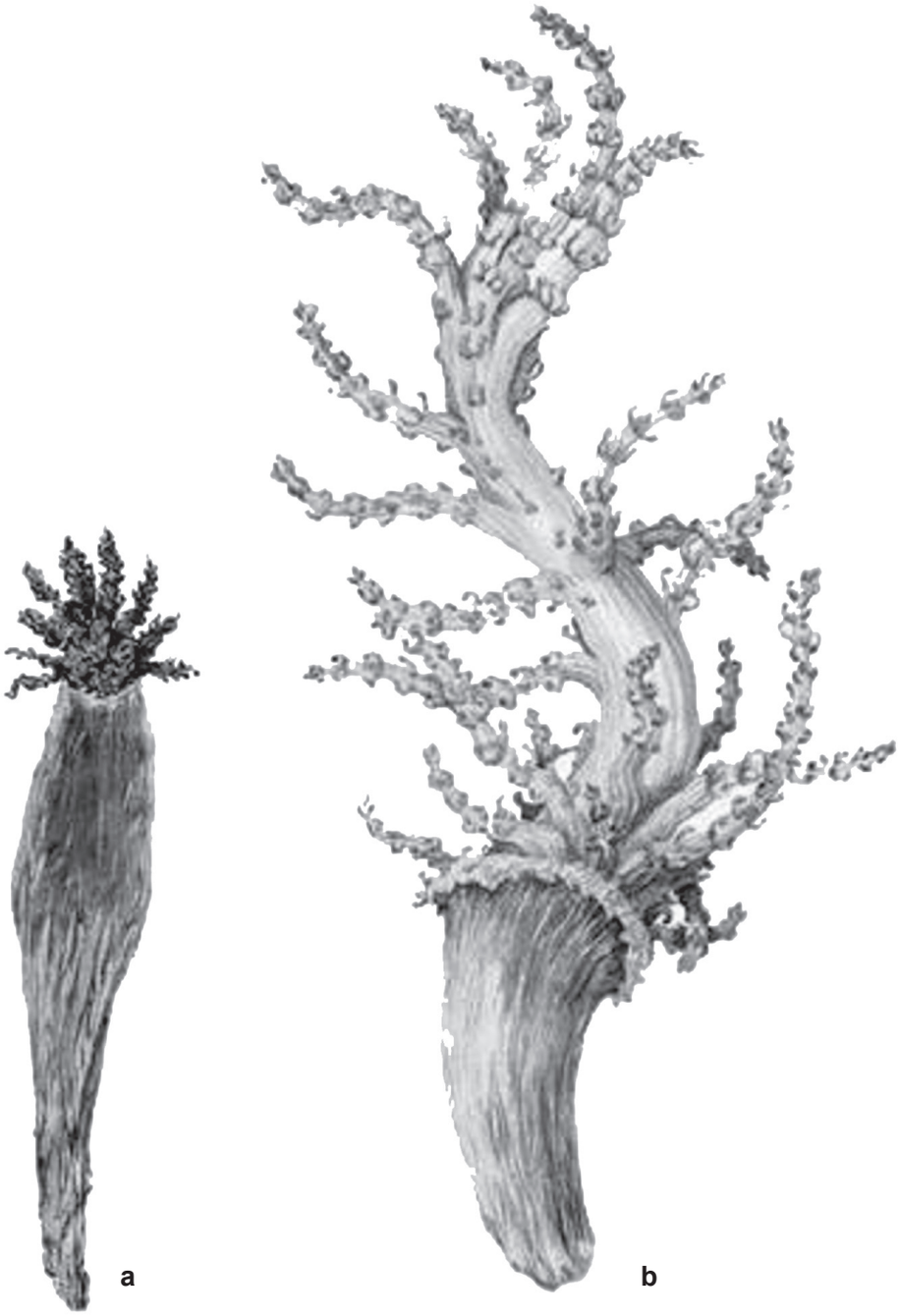

Figure 1: Studeriotes *species exhibiting a) retracted and b) expanded morphology. After Thomson and Dean, 1931.*

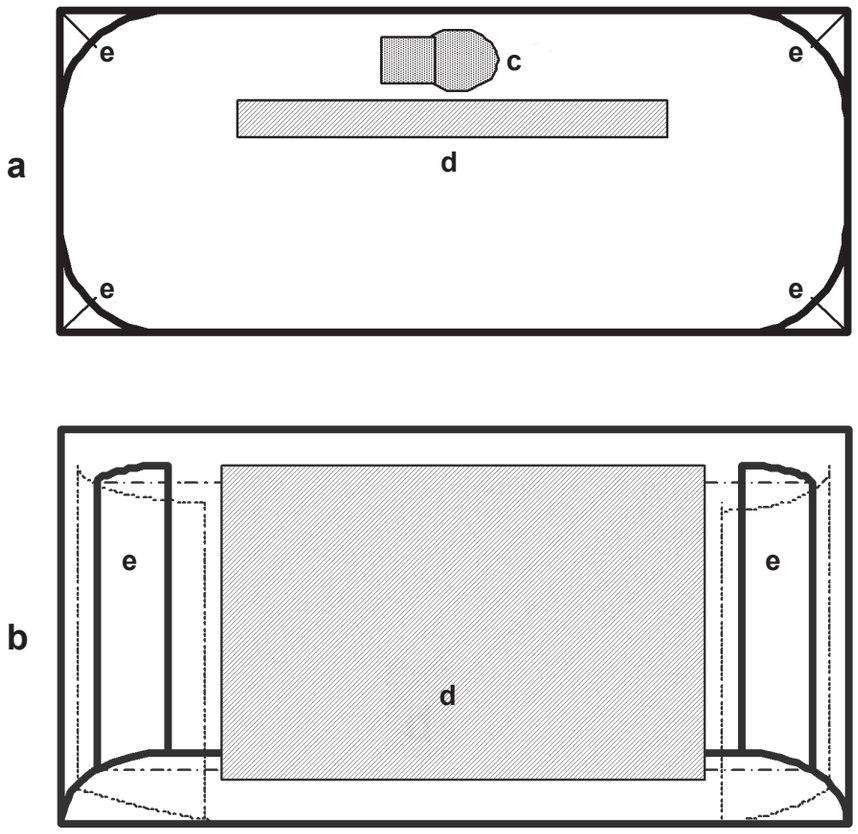

Figure 2: Laminar water flow aquarium design: a) top view, b) front view, c) pump with eductor, d) vertical partition, e) curved water flow baffles.

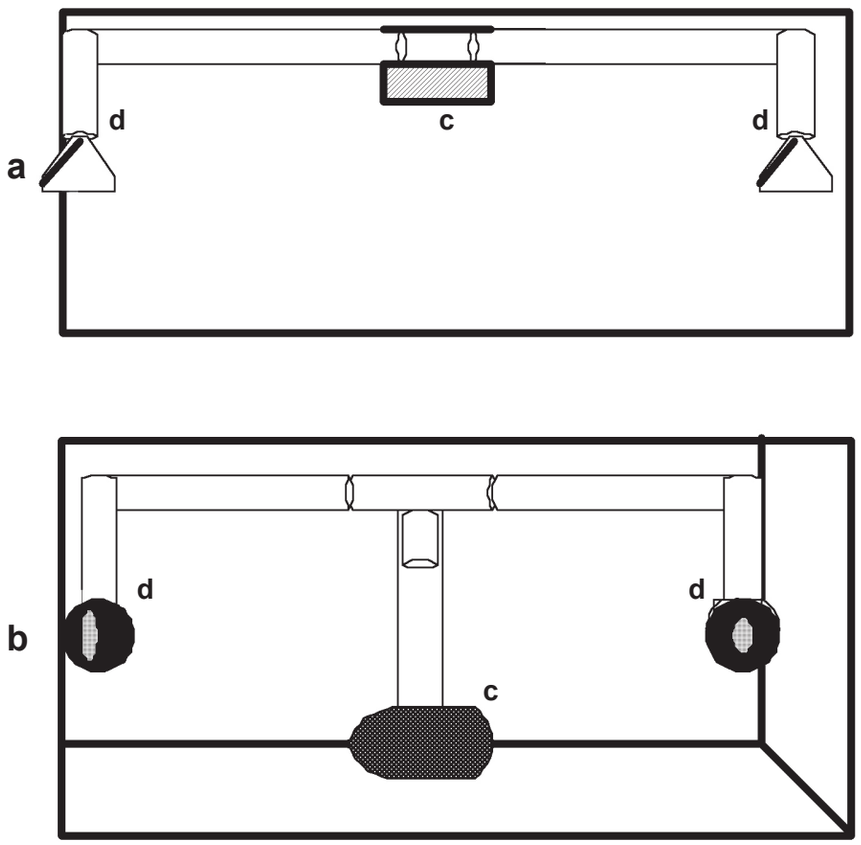

Figure 3: Oscillating water flow aquarium design: a) top view, b) front view, c) pump connected to output manifold, d) rotating water flow deflectors.

acquired and all were identified as *S. spinosa* based on sclerite examination. Five specimens of *S. spinosa* were a white color morph and four were black. The Atlantic species *Diodogorgia nodulifera* and *Swiftia exserta* were obtained from divers in the Florida Keys and identified using Bayer (1961) in the same manner.

Systems

Two different closed system aquariums were designed for the azooxanthellate gorgonians. The first system held 300 liters of water and was built to provide a directional laminar water flow. A second aquarium was created to produce oscillating water currents, but its volume was slightly smaller at 227 L. Both aquarium life support systems were maintained similarly using filtered natural seawater, a protein skimmer, and weekly twenty percent water exchanges. The water quality parameters for both systems are given in Table 1. Weekly water exchanges at twenty percent of the volume of each system sufficiently offset the nutrient influx introduced by feeding. Trace elements and calcium were also kept at near natural seawater levels by performing the weekly water changes. Alkalinity levels were maintained with the addition of a sodium bicarbonate buffering compound mixed into de-ionized water and used to replenish for evaporation.

To fabricate the laminar water flow system, a rectangular aquarium was partitioned lengthwise with a one centimeter thick piece of acrylic placed vertically in the middle. This divider was shorter than the length of the aquarium, which left an open space at either end. The rear portion of the tank created by the partition housed a submersible pump with an eductor mounted to it. Acrylic baffles with a curved radius were placed in the four corners of the aquarium (Figure 2). The result was a water stream created by the pump that flowed in one direction from behind the partition around the aquarium, directed by the baffles.

Table 1: Average water chemistry parameters in the gorgonian test systems.

Temperature	26-27 °C
Salinity	33-34 ppt
pH (average)	8.3
Nitrite	0.0 mg $NO_2^-.L^{-1}$
Nitrate	< 20 mg $NO_3^-.L^{-1}$
Ammonium	0.0 mg $NH_4^+.L^{-1}$
Calcium	380-410 mg $Ca^{2+}.L^{-1}$
KH	8.0 dKH
Phosphate	< 0.05 mg $PO_4^{3-}.L^{-1}$

An oscillating water current flow was designed for the second system. A submersible pump was placed at the lower rear portion of the aquarium. A water return manifold was constructed with two ports on either side of the aquarium. The water output stream flowed through rotating water deflectors (Figure 3). Each deflector had a rotational position opposite the other that produced a swaying water motion from one side of the tank to the other. By adjusting the size of the pump in both aquarium systems comparable water velocities in both systems could be achieved.

A 3,785-liter coral reef exhibit at AquaTouch was used to test the captive husbandry requirements for *Studeriotes* species. The refugium of this exhibit (Figure 4) was partitioned and nine

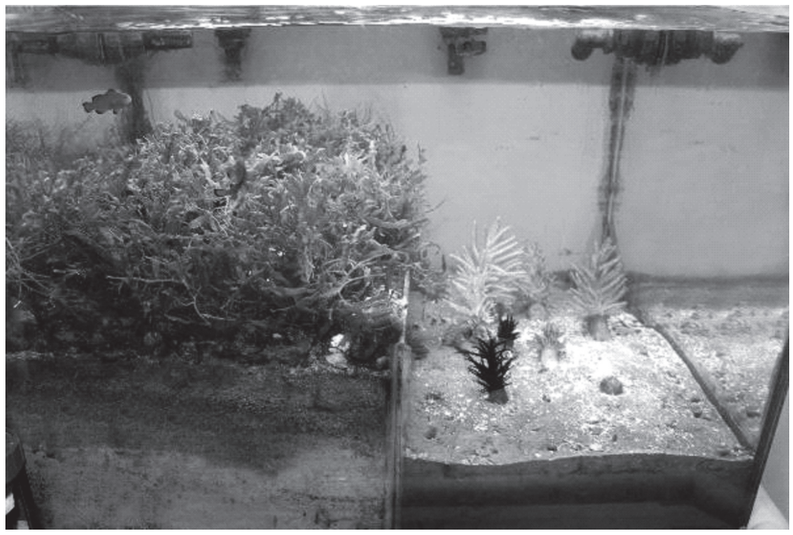

Figure 4: Refugium habitat used for the husbandry of Studeriotes *species.*

specimens were introduced in May of 2006. The portion of the refugium used in the experiment contained 2,322 cm^2 of substrate with a depth of 18 cm. Filtered natural seawater in the system flowed through the refugium exposing the corals to a variable water velocity of 3 to 6.5 $cm.s^{-1}$. This habitat received a diurnal light cycle with a twelve-hour photoperiod. The water chemistry of the system was highly stable, despite an average evaporation rate of approximately 76 liters per day. Water parameters were maintained as follows: salinity at 33 ppt, temperature at 26° C., calcium at 410 $mg.L^{-1}$, alkalinity at 8 dKh, phosphate levels below 0.01 $mg.L^{-1}$, and nitrate levels at a maximum of 5 $mg.L^{-1}$.

METHODS

Gorgonians

Two colonies of the five different species of gorgonians less than 20 cm tall were selected. One colony of each species was placed in the laminar and oscillating test systems for a total of five specimens in each of the two aquariums. They received portion-controlled feedings and were subject to two different water flow forms, laminar and oscillating. The purpose of these two systems was to compare growth rates in the gorgonians under different artificial water flow forms. Water conditions and growth data were collected for a period of one year. Each colony in both test systems had five different sections of the branches randomly selected for polyp analysis. The polyps were measured and a mean average diameter was determined. Polyp densities were also calculated for these same branch sections.

Colonies were secured to the rock structure, which was comprised of natural live rock. The gorgonians were positioned far enough apart so that they would not come into contact with each other, approximately 8 cm.

Water flow velocities within each of the two differently designed aquariums ranged from a minimum of 4 $cm.s^{-1}$ in the lowest flow regions to a maximum of 18 $cm.s^{-1}$, close to the output of the circulation pumps. Gorgonians were placed into an area of each of the two systems where they received near identical flow rates between 7 and 12 $cm.s^{-1}$. This range of water velocity was selected based on published values for a variety of reef corals (Figure 6). Once mounted on the rocks, the gorgonians were kept in the same location receiving a fixed water velocity across the colony for the duration of the growth experiments.

Both gorgonian aquarium systems received identical feeding regiments. The foods were a mixture of phytoplankton and zooplankton. Densities of plankton were determined by placing 0.5 ml of each on a hemocytometer and counted under a compound microscope. Three replicates of each were counted and a mean average was determined. Final concentrations were achieved by adjusting the densities of each plankton components. A commercial

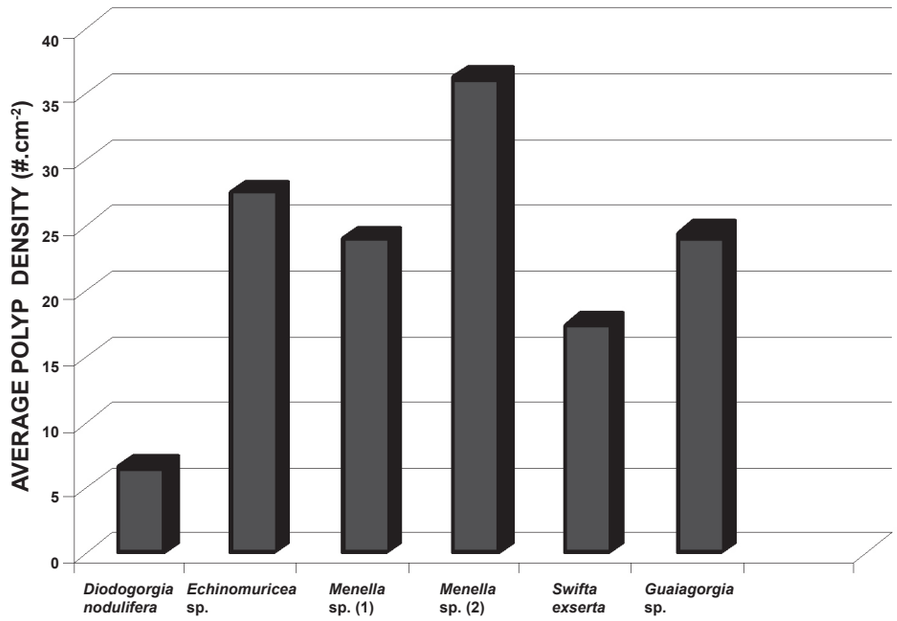

Figure 5: Average density of polyps per square centimeter of branch tissue in the five gorgonian species used in these experiments. A preserved specimen of Guaiagorgia *species was examined for comparison.*

aquaculture blend (Reed Mariculture, USA) of phytoplankton cells in the range of one to 15 µm was provided along with live cultures of *Nannochloropsis, Isochrysis,* and *Tetraselmis*. The zooplankton diet components were divided into a percentage of the total particle count. It was comprised of 70 % frozen oyster eggs (DT's Plankton Farm, USA), 5% frozen *Daphnia* (Hikari, USA), 10 % live *Artemia* nauplii, 10 % frozen copepods (JEHM Co.,USA) and 5 % live rotifers. These were mixed together with the phytoplankton and diluted in one liter of seawater. The foods were then aerated to keep the particles in suspension and dripped into each of the test tanks over a four-hour period. Three different feeding concentration trials were given. Calculations for the density of food particles were based on the final density that would be in the aquarium after all the food had been dosed. The first test had a concentration of 250 algal cells.ml^{-1} and 25 zooplankton particles.ml^{-1}, which was fed for a period of two weeks. The second feeding test had a concentration twice the amount of the first and was fed over the following two weeks. The final feeding trial contained 1,000 algal cells.ml^{-1} and 100 zooplankton particles.ml^{-1}. It was fed in the same manner as the previous two tests. This concentration was adopted as the food density given for the remainder of the growth experiment.

A random sampling of five polyps from each colony in each of the two test aquariums was dissected and examined under a compound microscope once per week during the first six weeks of feeding trials. The polyps were dissected one hour after the food mixture had completely dripped into the system. Polyps were checked for food particle consumption by examining the gastric cavity.

Linear growth measurements were made on colony branches. Branches were notched at the tip to expose the central axis located under the cortex or surface tissue layer upon arrival. The exposed branches were dipped into aniline blue stain at a concentration of 0.5 g.ml^{-1} until the stain penetrated the axis. Monthly growth measurements as linear extension were taken from the notch-stained area to the branch tip, and recorded. Additionally, new growth region diameters were measured with a micrometer at the same time and their average diameters were calculated.

Studeriotes

Nine colonies of *Studeriotes* were placed into three different size categories of marine aquarium substrates (CaribSea, USA and Walt Smith International, USA). Two random samples of 75 to 100 g from each of the three marine sediments were taken and analyzed following the methods given by Felix (1969). The samples were washed, dried and then placed in 10 cm diameter wire mesh sieves. Seven sieves of progressively smaller mesh sizes were used to trap each of the grain size

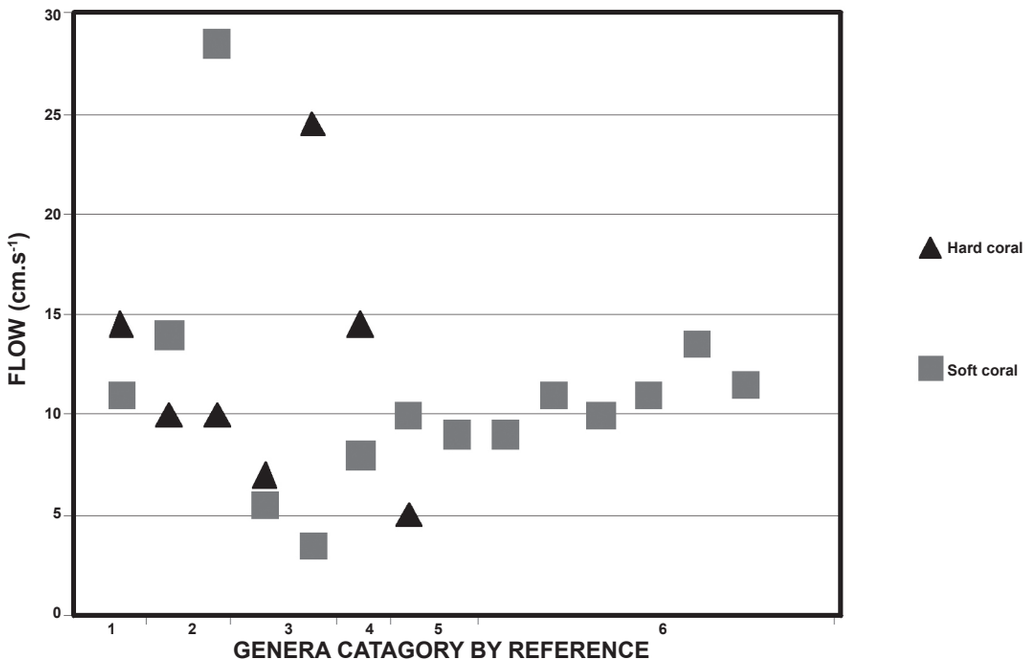

Figure 6: Flow velocities measured around coral colonies kept in captivity (6) and compiled from Dai and Lin (1993) (1), Levy et al. *(2001) (2), Patterson (1991) (3), Sebens (1992) (4), and Sebens and Johnson (1991) (5).*

categories (Figure 8, Y axis), which were then weighed and used to determine the mean percentage of total grain size composition from each of the three samples. All nine colonies were observed for a one-week period in each of the three substrates. A suitable material was selected based on their observed behavior during these trials.

Once a substrate had been selected, the *Studeriotes* colonies were exposed to different food particle sizes and monitored for a feeding response. A mean food concentration of 700 phytoplankton cells.ml^{-1} and 40 zooplankton particles.ml^{-1} was divided into three feedings over a 24-hour period. The foods were mixed together and introduced at the same time each day. As in the gorgonian experiment, the zooplankton components were divided into a percentage of the total particle count. A combination of 10 % rotifers (90-240 µm), 70 % oyster eggs (25-50 µm) and 20 % frozen copepods (750-800 µm) made up the majority of the zooplankton diet. Additionally, live *Artemia nauplii* and frozen *Daphnia* sp. were added as 10 % of the diet when live rotifers were unavailable. Polyps were randomly selected, fixed, dissected and examined for food consumption. Observations of growth were recorded with digital photography and a reference scale while these corals were kept in the exhibit.

RESULTS

Gorgonians

The five species of azooxanthellate gorgonians that were chosen met the criteria of relatively large polyps that were loosely spaced along the branches. Figure 5 illustrates the range of polyp densities among the specimens used in this experiment. A preserved species of *Guaiagorgia* with expanded polyps was examined for comparison purposes. Among the specimens that were tested, two Atlantic species, *Diodogorgia nodulifera* and *Swiftia exserta* had the fewest polyps per square centimeter. The remaining three species that were used in the test tanks exhibited polyp densities from 23 to 36 polyps.cm^{-2}. The three Pacific Ocean species also had on average smaller polyp diameters than the two Atlantic specimens.

All of the azooxanthellate gorgonians were placed in flow regions with an average velocity of 10 cm.s^{-1} after testing them under lower velocity conditions prior to the start of the feeding trials. At this velocity the polyps were fully extended. The 10 cm.s^{-1} flow speed prompted over 90 % of the polyps in each colony to fully extend in the laminar flow system. The oscillating flow patterns in the second tank design showed similar polyp extension.

Feeding trials were carried out in both systems for a six-week period. The average prey consumption was taken from randomly selected polyps from colonies in both of the test systems. Polyps that received a concentration of 250 phytoplankton cells.ml^{-1} and 25 zooplankton pieces.ml^{-1} during the first two weeks in captivity showed on average less than 10 particles in the gastric cavities per colony from randomly sampled polyps. In the second two-week period, when the food concentrations were doubled there was an increase in the concentration of ingested food particles. They now averaged four particles per polyp per colony. When the concentration was further increased to 1,000 phytoplankton cells.ml^{-1} and 100 zooplankton pieces.ml^{-1} there was an average food particle count of seven pieces per polyp per colony present in the digestive cavity. Random dissection of polyps during the course of this experiment showed the level of consumption remained consistent in the colonies. The remaining eleven months of this study was used to monitor any growth in the colonies.

Although both the laminar and oscillating water flow designs successfully maintained the test gorgonians, there was a difference in their linear rates of growth. All of the colonies in the laminar flow aquarium showed an average growth rate that exceeded those in the oscillating system. *Menella* species (1) grown in the laminar flow aquarium exhibited an average growth rate 0.20 cm per month more than the same species in the oscillating flow system. Similar growth occurred in *Menella* species (2) with a 0.17 cm per month increase over the same species grown under oscillating flow conditions (Figure 7). There was a slight increase in the growth of *Diodogorgia nodulifera* with an average of 0.02 cm per month and *Swiftia exserta* at 0.03 cm per month over the same species grown in the oscillating flow aquarium. The *Echinomuricea* species exhibited nearly identical average growth rates under the two different flow environments. The oscillating flow system produced a growth rate in *Echinomuricea* that averaged 0.30 cm per month. In the laminar flow system *Echinomuricea* grew at an average rate of 0.32 cm per month. All of the branch diameters in new growth regions of colonies grown in the laminar flow aquarium were

between 0.01 and 0.03 mm larger in diameter than the same species from the oscillating flow aquarium.

Studeriotes

Nine colonies of *Studeriotes* species were monitored for 11 months in the closed system exhibit. During this time, all nine corals were successfully maintained without any mortality. Each of the specimens exhibited what appeared to be a natural cycle of expansion and contraction of the upper portion of the stalk at irregular intervals. Neither the introduction of food or manipulation of the photoperiod appeared to affect the colony expansion cycle. The corals received the same concentration and variety of foods throughout the course of this study. Each colony had randomly selected polyps sampled for food consumption. The polyps were dissected and microscopic examination revealed both phytoplankton cells and zooplankton in the gastric cavity. Only the copepod component of the zooplankton diet could be identified.

Colony expansion behavior, burying of the basal cup, and colony orientation in an upright manner were indicators used for selecting a substrate. Three substrate materials were

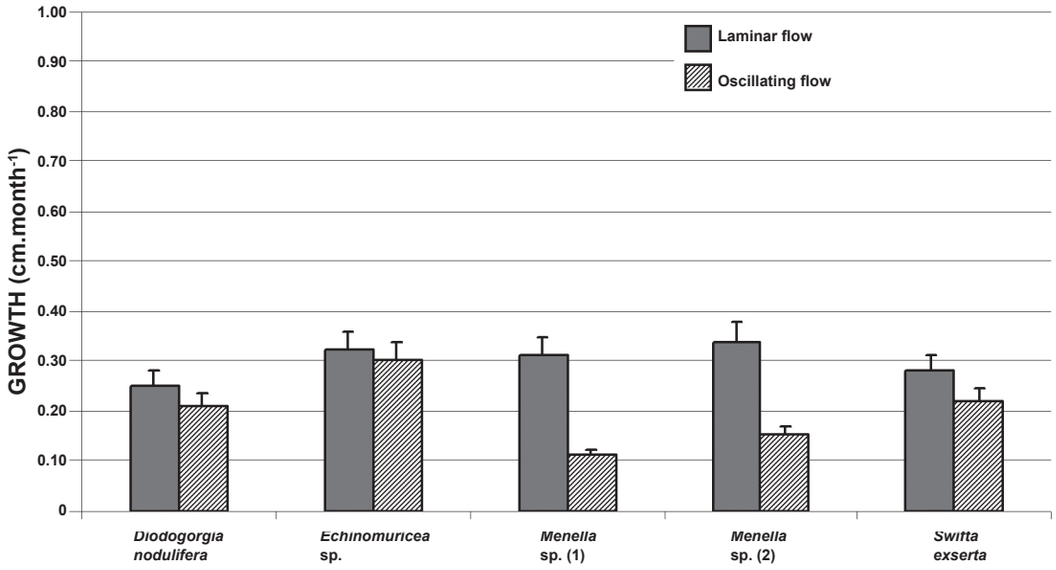

Figure 7: Comparison of growth rates in colonies maintained in the laminar and oscillating flow systems.

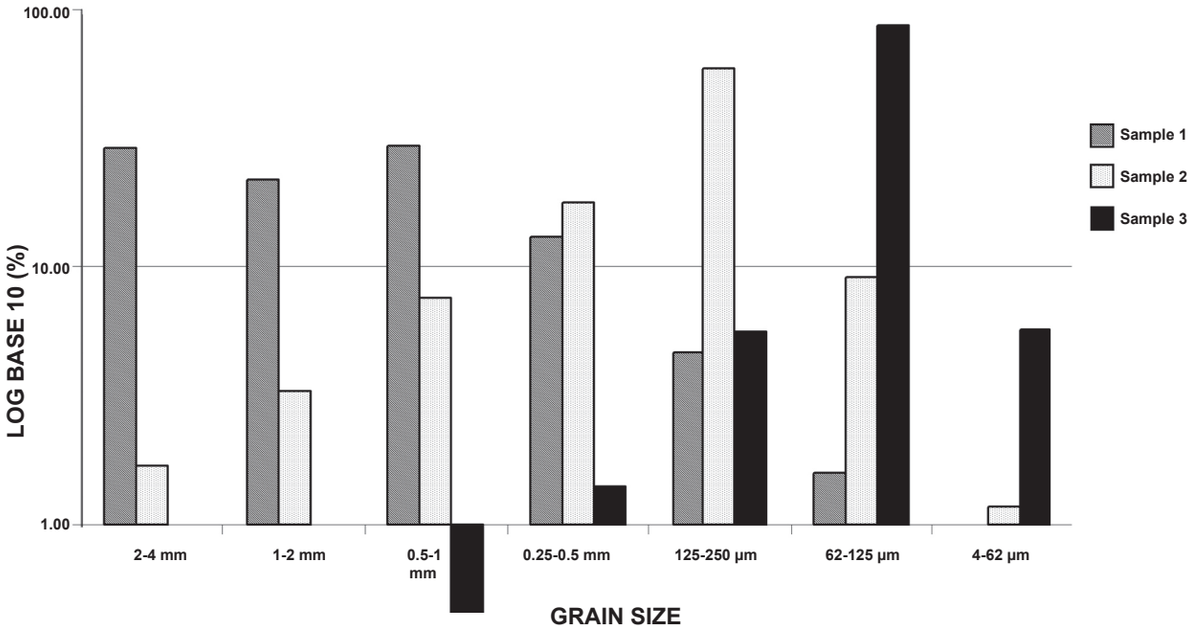

Figure 8: Grain size analysis of the three different sediment samples used in the Studeriotes *habitat.*

analyzed for grain size content. A percentage of each size category in proportion to the total was determined and the comparison is given in Figure 8. Sample 1 had the largest percentage of large grain sizes with over 80 % of the grains larger than one millimeter in diameter. All nine colonies were observed in this sediment sample for one week. Most of them could not bury the lower portion of the colony and would lay expanded on their sides. The few colonies that would stay with the lower cup portion embedded in the sediment would often turn from side to side and rarely remain in an upright position. After two weeks of observations the colonies were transplanted into the second sediment sample. In this test the combined percent of grain sizes larger than one millimeter was only 12.6 % and the majority of composition had grains in the 125 to 250 µm category. Colonies were observed for two weeks in the second sample and over half of the specimens maintained an upright position while in an expanded state. The basal portion of these same colonies stayed buried in the substrate. Colonies were then moved into the third substrate samples where they were maintained for the remainder of the experiment. This sample had a very fine, silt-like composition. Over 92 % of the grains in this substrate were smaller than 125 µm. All of the nine colonies of *Studeriotes* settled into this substrate with the basal portion fully submerged. Most colonies would expand into an upright position and maintain a rigid expanded state without rotation or bending of the lobes.

DISCUSSION

Gorgonians

Five species of azooxanthellate gorgonians were maintained in two different water motion systems for a period of one year. During this time it was possible to keep them in an apparently healthy state under captive conditions and measure growth in the colonies. With no mortality and new growth in the branches, this experiment was considered successful. The key factors in captive husbandry of these particular gorgonian species appears to be careful selection of specimens potentially well suited for closed system aquarium environments based on their polyp sizes and densities, the availability of specimens shipped in a minimal amount of time, packaged in a favorable manner, and placed in an aquarium system designed to meet their nutritional and prey capture needs.

Both of the gorgonian test tanks maintained the same range of water flow velocities. A behavioral observation was made in the gorgonians under these flow conditions. Regions in the two aquariums that had less than 7 $cm.s^{-1}$ of flow prompted fewer gorgonian polyps to expand and capture food in initial water flow tests prior to their final placement on the rocks. An illustration of water current velocity ranges for captive grown zooxanthellate soft and hard corals is given in Figure 6. Based on this water current chart, the colonies were placed in regions of the tanks where flow velocities were 10 $cm.s^{-1}$. Since neither flow pattern showed a difference in polyp expansion, the comparison of these two gorgonian groups suggests that polyp expansion is a water current velocity mediated response and not a flow direction response. It would appear that this is a good general starting velocity for captive care of azooxanthellate gorgonians, although other gorgonians could require higher or lower water currents.

Colony size is another factor that might influence water velocity requirements in closed systems. Measurements of water current velocities in the vicinity of *Gorgonia ventalina* off the leeward side of Cozumel Island in the Yucatan ranged from 4 to 6 $cm.s^{-1}$ in shallow water (<10 m) where colonies were less than 25 cm high. Deeper water (>40 m) colonies of *G. ventalina* in high current would show current velocities that exceed 30 $cm.s^{-1}$ (M. Janes, unpublished data). Anecdotal observations suggest that smaller, zooxanthellate octocorals will adapt to captive systems when smaller specimens are transplanted and allowed to grow into the environmental conditions. It is reasonable to assume that this same acclimatized growth might occur in azooxanthellate octocorals although there is no data yet to support this assumption.

If growth is considered in the results comparing the two system designs (Figure 7) then there was little difference between them in three of the four genera that were tested. The laminar flow system resulted in notably increased growth rates in the two *Menella* species. It is likely that both of the two experimental systems were small enough to maintain the food particle densities in suspension long enough for colonies to benefit from it. Also, because there was limited biodiversity in these systems there was no direct competition for plankton.

A variety of foods have been investigated

regarding the diets of soft corals. Among the more noteworthy results, Fabricius *et al*. (1995b) identified phytoplankton as a major component in the diet of three Red Sea azooxanthellate octocorals. Further investigations showed that phytoplankton uptake varied with cell density, exposure time and from one species to the next (Widdig and Schlichter, 2001). Additional prey items consumed by azooxanthellate octocorals include bacteria, nanoflagellates, ciliates, and diatoms (Orejas *et al*., 2003). Octocorals in general are at a disadvantage in the capture of motile zooplankton organisms due in part to their small polyp sizes and the limited number or absence of nematocysts. Smaller "pseudo" zooplankton choices and phytoplankton were successful dietary components used to maintain the gorgonians in this study. However, it is unclear what the minimum food concentrations are for the species maintained in this study. The upper limit of the food particle density was based on water quality parameters and not a result of a detailed analysis of the gorgonians nutritional uptake.

While both systems provided for growth in the azooxanthellate gorgonians used in these experiments, the laminar flow system showed a higher growth rate. There are many factors that can influence growth rates in octocorals including, vegetative versus sexually reproduced colonies, size and shape. Age is also a factor, as in the case of *Acabaria biserialis* and *Leptogorgia virgulata* where young recruits exhibited growth rates of 1 cm per month (Zeevi Ben-Yosef and Benayahu, 1999). There are also differences in growth rates from the wild and those recorded in captivity. Members of the zooxanthellate octocoral genera *Sarcophyton* and *Sinularia* kept in aquaria may exceed growth rates of 1 cm per month (Delbeek and Sprung, 1997). Yet species of these same genera on the Great Barrier Reef, Australia can have a maximum growth rate of 0.12 cm per month (Fabricius, 1995a) in colonies that are likely to be much older. In another study of shallow-water gorgonians, the average growth rate for species of the genus *Pseudopterogorgia, Pseudoplexaura, Gorgonia, Eunicea,* and *Plexaura* was found to be approximately 0.16 cm per month (Yoshioka and Yoshioka, 1991). The average growth rate of the five species in this study was 0.3 cm per month in the laminar flow system and 0.2 cm per month in the oscillating flow system. It is difficult to determine whether or not the growth rates achieved in this study are above, below, or average in comparison to wild colonies without field data.

The method chosen to measure growth for this study offered some challenges. By marking the branch tips upon arrival, the notch in the branch tip used to expose the axial skeleton added stress to the colony. It also created a potential pathway for pathogenic infection and or algal colonization. Further, the aniline blue stain required many minutes to penetrate the central core and over time it became difficult to identify as new tissue grew from the branches. The photographic method given by Lasker *et al*. (2003) and used by other researchers is a less invasive method to measure growth.

Studeriotes

Nine colonies of *Studeriotes* were successfully maintained in a closed system for an eleven-month period from 2006 to 2007. At this point the observations and data were tabulated while the colonies continued to flourish. Species belonging to this genus appeared to be good candidates for a captive husbandry program despite the limited amount of published information on them. They met the criteria of having relatively large, widely spaced polyps and the only apparent challenge in developing a suitable habitat for them was to identify an appropriate substrate.

The water velocity range of 3 to 6.5 $cm.s^{-1}$ was selected based on similar flows found in lagoonal habitats and protected areas where *Studeriotes* species were known to occur (Venkataraman, pers. com.). There was no indication in this study that the irregular intervals of colony expansion and contraction or the occasional maneuvering of the basal portion in colonies out of the substrate was a result of the relatively low water velocity. Observations of prey capture were made among the nine colonies that were used in this experiment which was another indicator that the water flow was not too strong in the vicinity of the colonies. It is possible that increasing the water velocity might affect the behavior of these corals but no tests were performed. Although some polyps were examined for food particle ingestion in the gastric cavity, it was unclear which particles provided the primary source of nutrition. The nine *Studeriotes* colonies were capable of being maintained in a closed system on the diet that was provided to this exhibit. A more detailed study of feeding preferences and particle densities could yield valuable data for this genus of corals.

Substrate selection was initially considered an

important factor in the habitat design for this coral. Observations during the testing process of different grain sizes indicated that species of *Studeriotes* were responding to the degree of difficulty in attempts to bury their basal cup portions. With the final introduction of very fine, silt-like sediment, all of the colonies rapidly buried their basal cups and the expanded portion of lobes remained orientated upright in the water column. In the months that followed their introduction into the third substrate sample some colonies would come out of the substrate and appear to lay on the surface of the substrate, though this occurred very infrequently. A search of the published literature revealed no mention of this behavior in the wild.

In addition to the regular feeding regiment of prepared plankton foods the sediment surface layer was occasionally disturbed, creating suspended fine particles in the vicinity of the colonies for a brief period of time. It is possible these disturbances liberated nutrients in addition to any naturally occurring plankton that might be present in the system. Both of these potential nutrient sources could provide supplemental nutrition to the coral colonies.

Early on in the husbandry of these *Studeriotes* species it was clear that it would be difficult to determine a growth rate. The extensive amount of expansion and contraction in colonies made it difficult to identify if they were getting larger, if the lobes were growing, when the maximum amount of expansion had been reached, or if they had reached an upper size limit for adult colonies. Photographic measurements were attempted by using both a grid pattern and scaled ruler as references in the image field. Unfortunately no method proved accurate and there was a significant amount of error from the difficulty in determining when the colony was completely expanded. Also, colonies would often change the orientation of their lobes in the water column making it difficult to reference particular lobes. After eleven months of observations it was obvious that the colonies were healthy, exhibiting normal behavior, and visually appeared larger than in the initial photographs taken after their introduction into the display.

CONCLUSION

This study has shown that there is significant potential to develop a long-term captive husbandry program for displaying some azooxanthellate octocorals. With additional funding, experimental design, and resources this study could be the foundation for future experiments in identifying the captive requirements of different azooxanthellate octocoral species. The results of these experiments are considered preliminary for two reasons. First, a “shotgun” approach to feeding of both the gorgonians and *Studeriotes* species was taken by offering them a variety of foods in the hopes that some foods would be both palatable and meet their nutritional requirements. A more comprehensive analysis of food particle consumption and nutritional benefits in regards to a colony’s carbon and nitrogen requirements would be useful. Secondly, not all octocoral species may be suitable for captivity. They could have husbandry requirements that cannot yet be provided for with existing systems, foods, and care protocols. Additional experiments, data collection, and wild observations will be necessary to identify long-term husbandry plans for azooxanthellate octocorals in captivity. The results of these efforts could be used to create attractive, brightly colored displays of azooxanthellate octocorals in aquaria that will educate and amaze the public.

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PERSONAL COMMUNICATIONS

Venkataraman, K., 2007. National Biodiversity Authority, Kerala, India.

INTERNET RESOURCES

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